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NEW DIRECTIONS FOR RC – AVOIDING TIME-BOMBS IN OUR COASTAL STRUCTURES

MIAMI

FDOT

Marco Rossini, Antonio Nanni, Ivan Lasa, Steve Nolan

Paper 119: New Directions for RC – Avoiding Time-bombs in our Coastal Structures

Abstract:
Within the last century, coastal structures for infrastructure applications have traditionally been built with timber, structural steel, and/or steel-reinforced/prestressed concrete. Given asset owners' desire for increased service-life; reduced maintenance, repair and rehabilitation liability; resilience; and sustainability, it has become clear that traditional construction materials cannot reliably meet these challenges without periodic intervention. Fiber-Reinforced Polymer (FRP) composites have been successfully utilized for durable bridge applications for more than three decades, demonstrating their ability to provide a reduced maintenance costs, extend service life, and significantly increase design durability. This paper explores these applications, related specifically to internal reinforcement for concrete structures in both passive (RC) and pre-tensioned (PC) applications, and contrasts them with the time-dependent effect and cost of corrosion in coastal transportation infrastructure. Recent development of authoritative design guidelines within the US and international engineering communities will be summarized and case-studies comparing traditional RC/PC verses FRP-RC/PC will be presented to show the sustainable (economic and environmental) advantage of composite structures in the coastal environment.

New Directions for RC – Avoiding Time-bombs in our Coastal Structures

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Low durability of concrete elements due to steel corrosion – cases wherein the steel reinforcing bars acted as an internal clock bomb

Lino Maia[ab]*, Sérgio Alves[b]

Victorian Concrete Cancer Warning - A Time Bomb Going Undetected

Published on April 14, 2015

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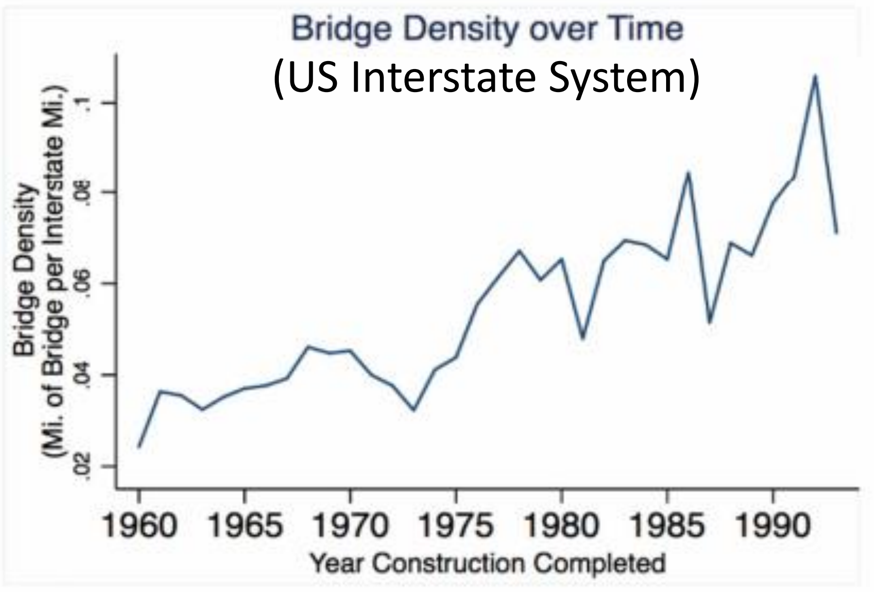
ACE Body Corporate Management - Media Release April, 2015

VICTORIAN CONCRETE CANCER WARNING – A TIME BOMB GOING UNDETECTED IN HUNDREDS OF VICTORIAN PROPERTIES

Introduction



Infrastructure owners are seeking:

- increased service-life;
- reduced maintenance & repair liability;
- resilience;
- and sustainability (sometimes!)

Traditional construction materials cannot reliably meet all these challenges without periodic intervention (corrosion mitigation & restrengthening):

- **USA** - total annual cost of corrosion in was reported as $276 billion in 2002.
  - Bridge decks maintenance due to corrosion is around $2 billion;
  - Substructure another $2 billion (FHWA, 2002) – *mostly from seawater.*
- **China** - the annual cost of corrosion is also estimated at ¥2 trillion (approximately US$290 billion) (CAS 2014).

CAS. 2014. "Corrosion Status of China and the Control Strategy Research," Chinese Academy of Sciences, Beijing, China, www.cas.cn.

The Inevitability of Corrosion in Coastal Structures

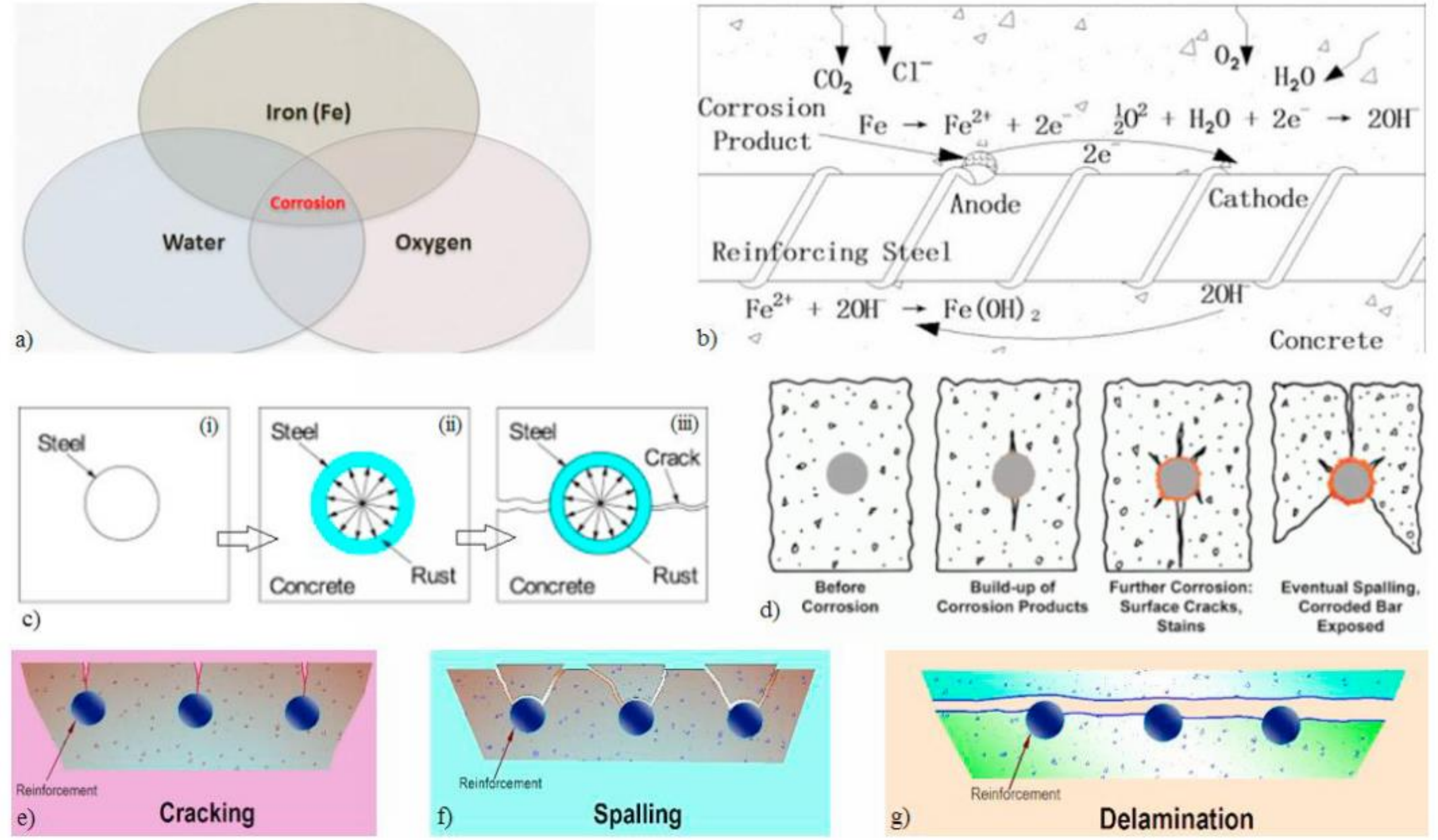
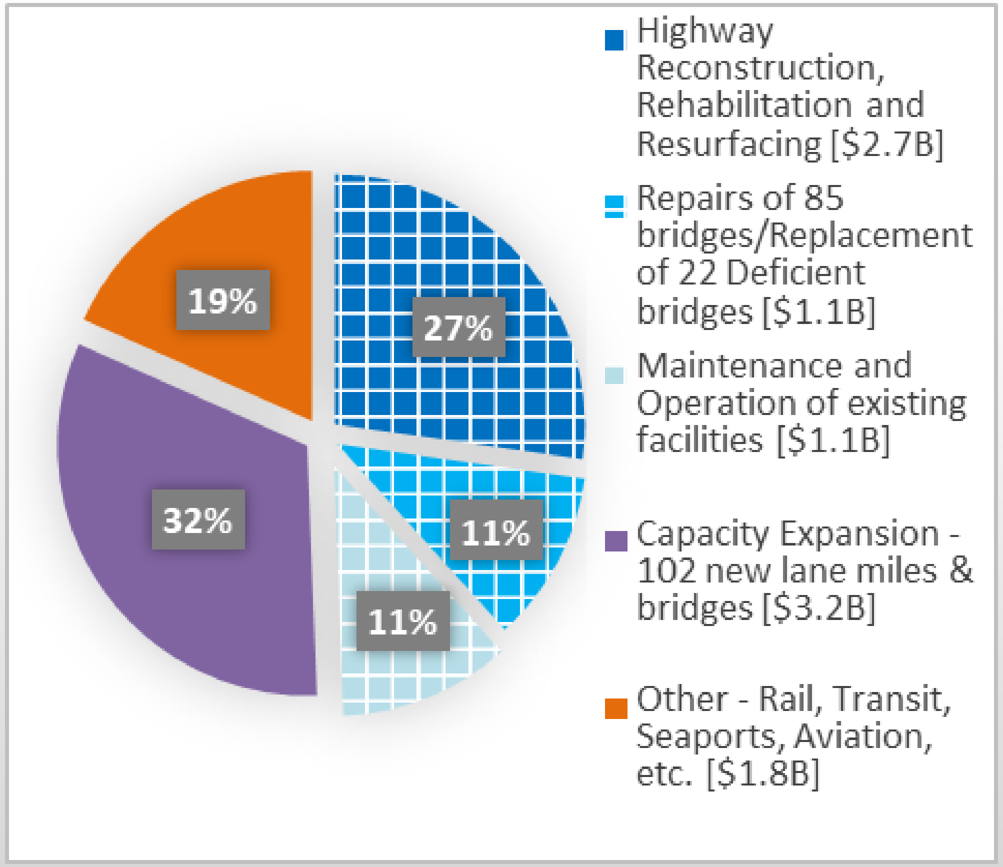


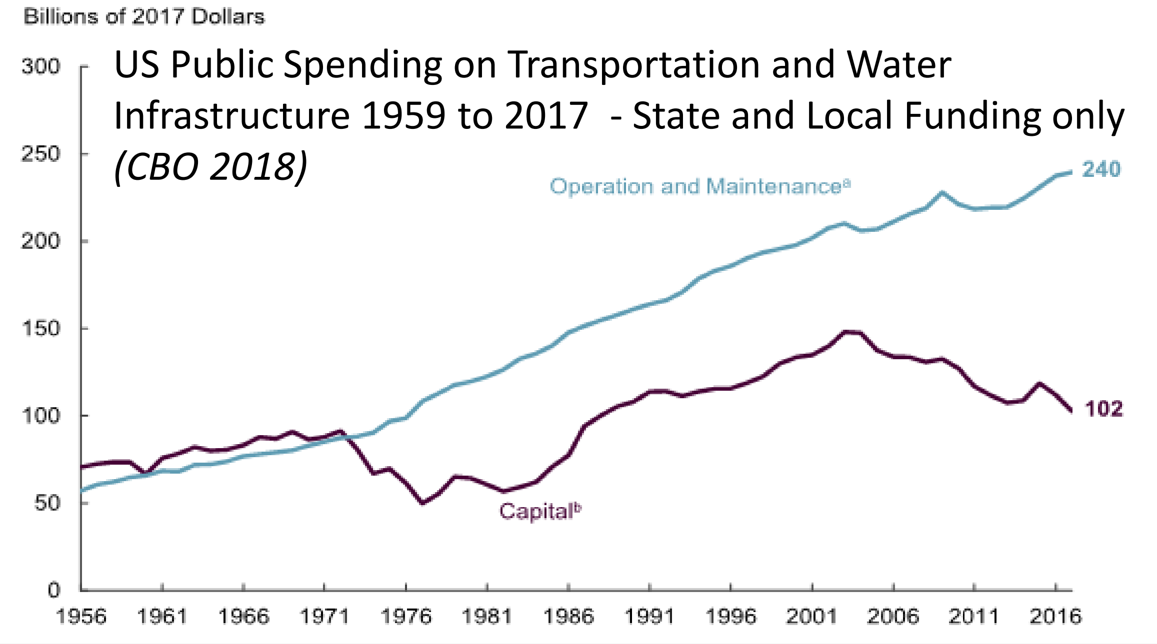
Figure 1. a) Components for corrosion; b) Electro-chemical process of corrosion; c) Generation of stress inside the concrete; d) Evolution of cracks as corrosion progresses; e) Cracks due to corrosion; f) Spalling due to corrosion; g) Delamination due to corrosion.

Corrosion Mechanism in Reinforced Concrete (from Maia & Alves, 2017)

Drastic Consequences Demand Different Solutions

Florida DOT Transportation Budget FY 2019/2020
- 49% for combined Maintenance, Repair , Rehab and deficient bridge replacement (hatched areas).





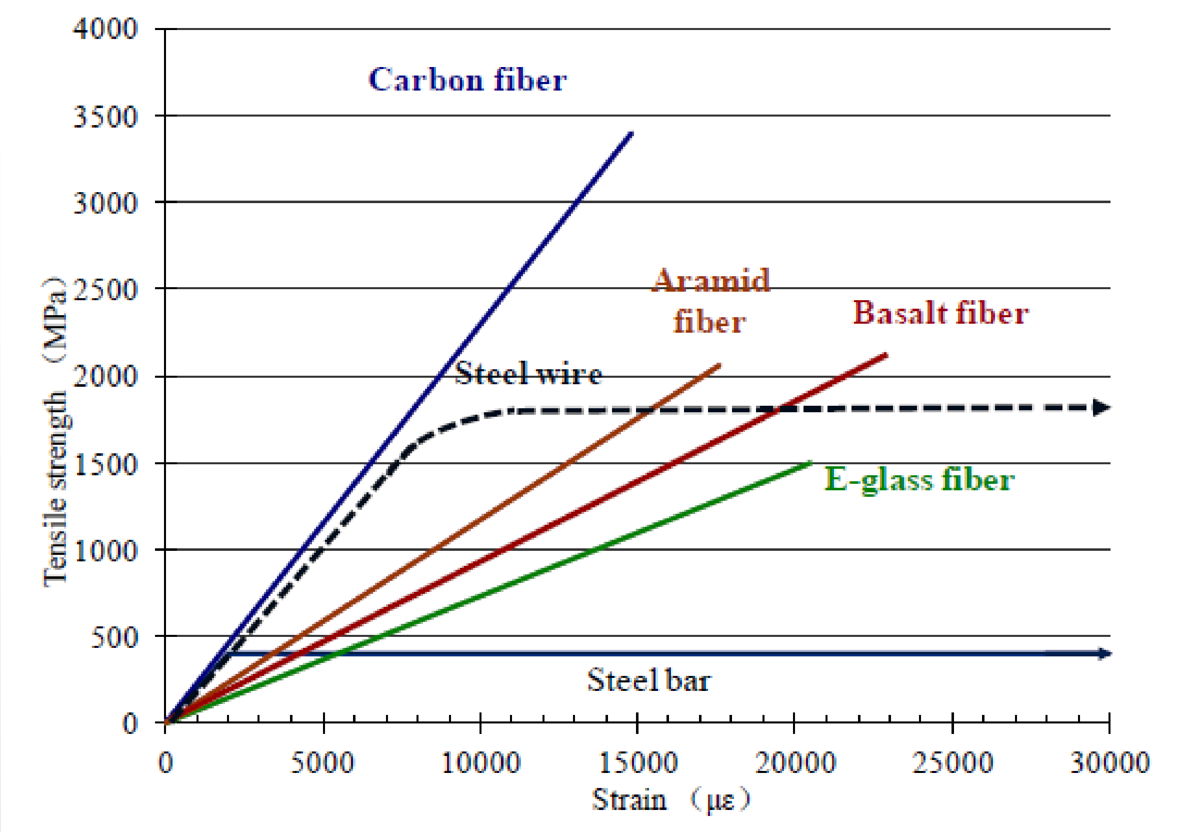
“Reduce the life cycle cost of infrastructure by 50 percent by 2025 and foster the optimization of infrastructure investments for society”

Drastic Consequences Demand Different Solutions

Fiber-Reinforced Polymer (FRP) composites have been successfully utilized for durable bridge applications for more 30+ years, demonstrating their ability to provide reduced maintenance cost, extended service life, and significantly increase design durability.

FRP materials of most interest to FDOT (currently):

- ***Carbon FRP strands and laminates*** *(PAN fiber with epoxy or vinyl-ester resin systems)*
- ***Glass FRP reinforcing Bars*** *(E-CR fiber with vinyl-ester resin systems);*
- ***Basalt FRP reinforcing bars*** *(melt fiber with epoxy resin systems).*



Case Study Examples

Case-studies show the sustainable (economic and environmental) advantage of composite structures in the coastal environment:

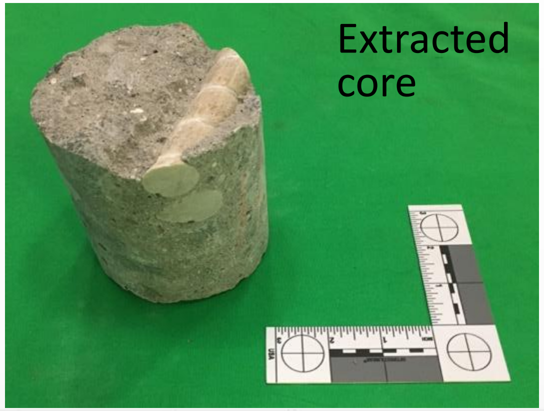
- **Ulenbergstrasse Bridge, Düsseldorf, Germany 1986 (GFRP-PC)**
- **Shinmiya Bridge, Japan 1988 (CFCC-PC)**
- **Beddington Trail Bridge, Calgary, Alberta 1993 (CFCC & CFRP-PC)**
- **Hall’s Harbor Wharf, Bay of Fundy, Nova Scotia 1999 (GFRP-RC)**
- **McKinleyville Bridge, West Virginia 1998 (GFRP-RC).**
- **Val-Alain Bridge, Quebec 2004 (GFRP-RC)**

Complete Highway Bridge Demonstration (FDOT):

- **Halls River Bridge, Homosassa, FL 2018 (GFRP-RC & CFRP-PC)**

Recent Durability Case Study

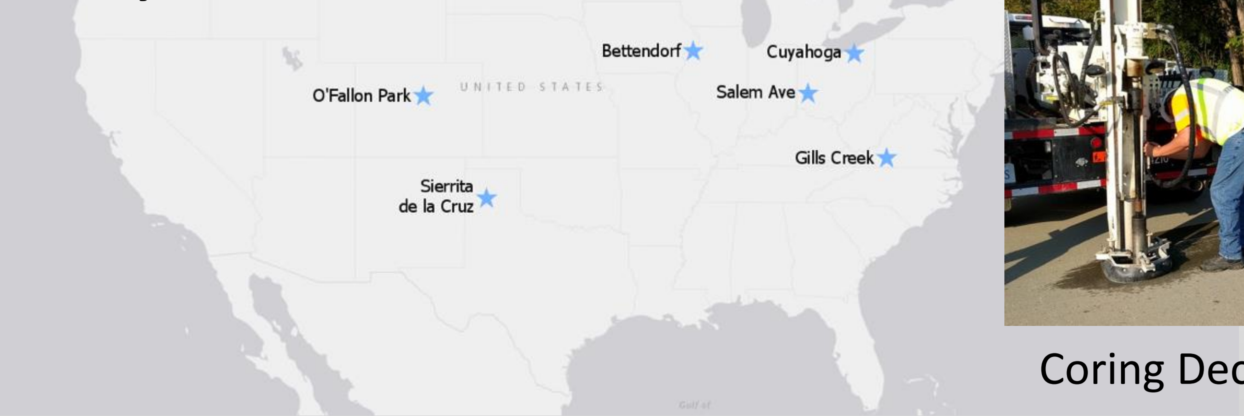
Evaluate the durability of GFRP rebars that have been in bridges across the US for 15+ years:

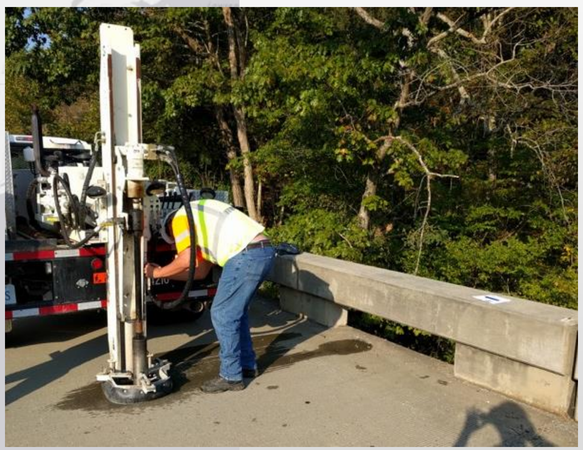


Sierrita de la Cruz Bridge- Amarillo, Texas -2000
Salem Ave Bridge- Dayton, Ohio - 1998
Bettendorf, Iowa - 2001
Cuyahoga County, Ohio - 2002
O'Fallon Park Bridge- Kittredge, Colorado - 2002
Gills Creek Bridge- Franklin County, Virginia - 2003

Coring arch at O'Fallon Park Bridge

Durability of GFRP rebars after 15+ years in service





Coring Deck – Gills Creek

PennState
Missouri S&T
Owens Corning
aci American Concrete Institute Always advancing
University of Miami
Strategic Development Council aci Foundation

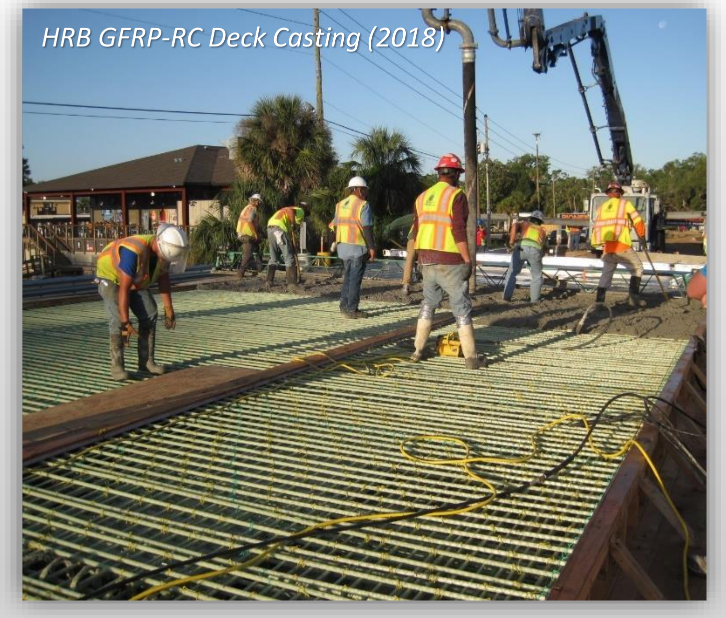
Case Study Examples - Halls River Bridge

Homosassa, FL 2018 (GFRP-RC & CFRP-PC)

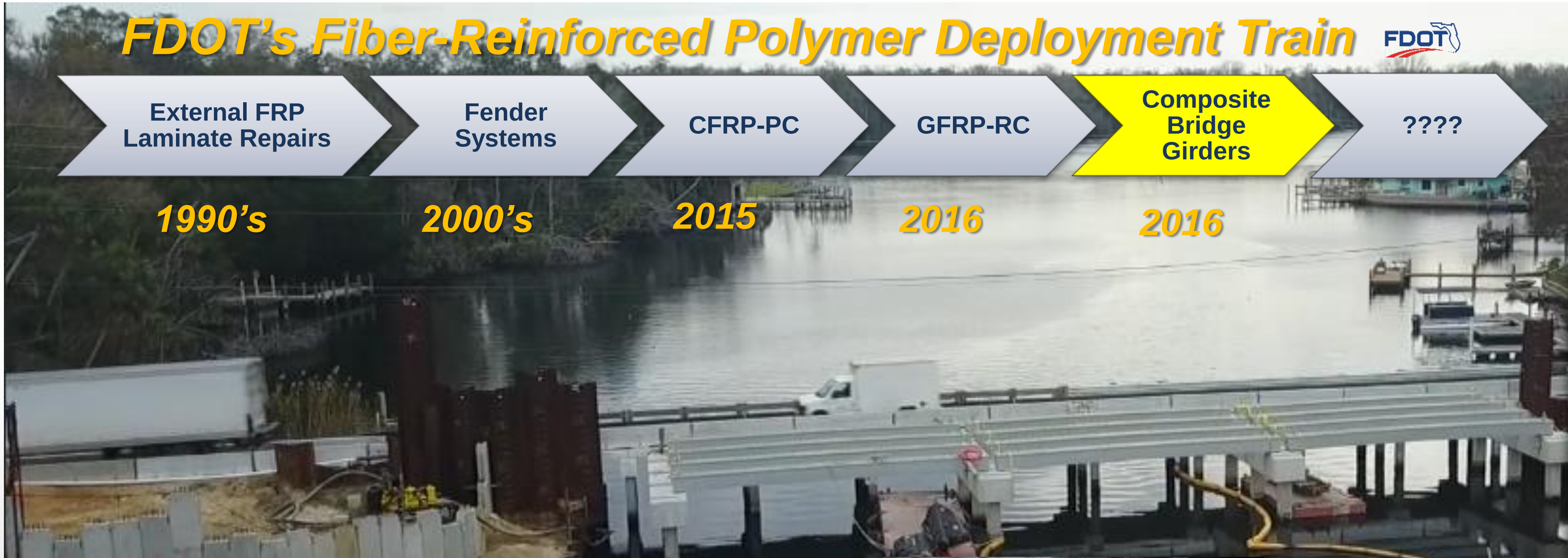
Five-span vehicular bridge entirely constructed using corrosion-resistant solutions and mostly FRP reinforcement including:

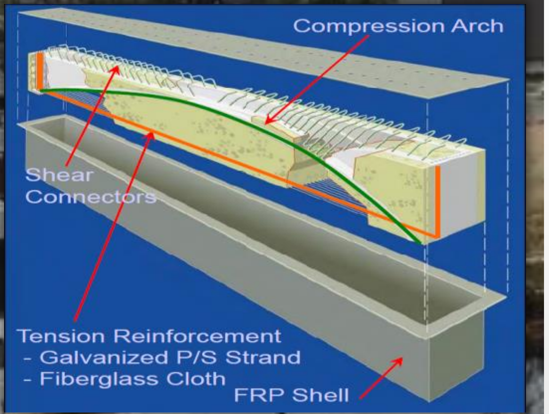
- CFRP-PC bearing piles;
- CFRP-PC/GFRP-RC sheet piles;
- hybrid HSCS-PC/GFRP-RC sheet piles;
- GFRP-RC pile bent caps;
- GFRP-RC bulkhead caps;
- GFRP-RC bridge deck
- GFRP-RC traffic railings
- GFRP-RC approach slabs
- GFRP-RC gravity wall.

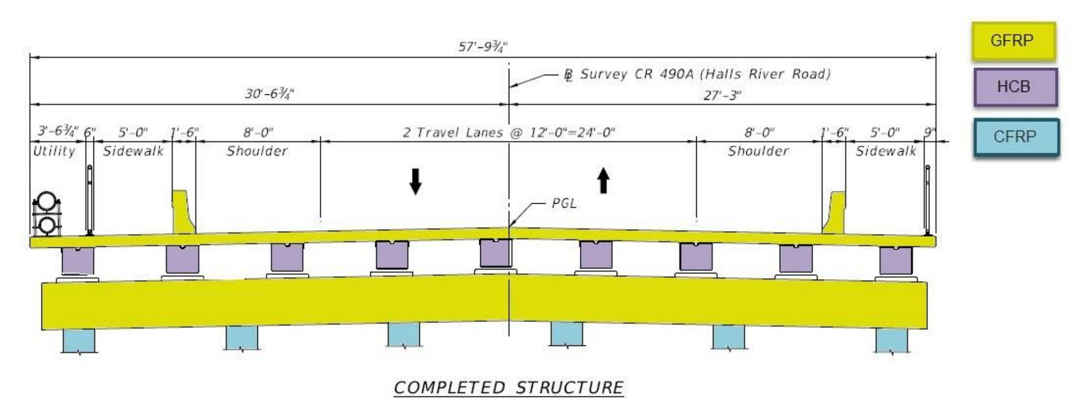

HRB GFRP-RC Bent Cap (2017)

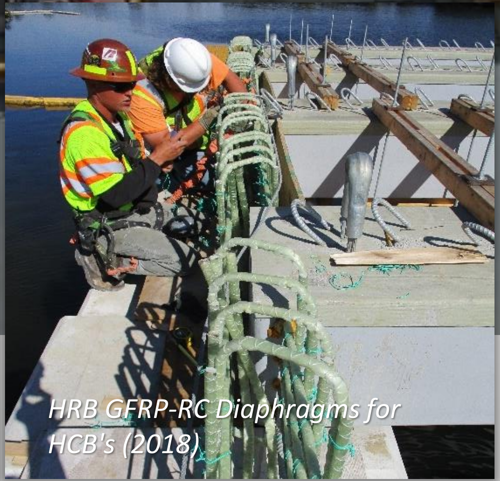

HRB GFRP-RC Deck Casting (2018)

Case Study Examples - Halls River Bridge








HRB GFRP-RC Diaphragms for HCB's (2018)


HRB Hybrid Composite Beams (2017)

Case Study Examples - Halls River Bridge

Homosassa, FL 2018 (GFRP-RC & CFRP-PC)

Five-span vehicular bridge

Conclusion

- 30+ years of field applications in bridge structures eliminating the ever-present risk of corrosion.
- FRP provides a durable reinforcement for:
  - increased service-life,
  - reduced maintenance costs,
  - Potential resiliency adaption and sustainability.
- 270+ bridges have been completed using FRP reinforcement in the US and Canada;
- 23+ CFRP prestressing in the US.

Questions

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